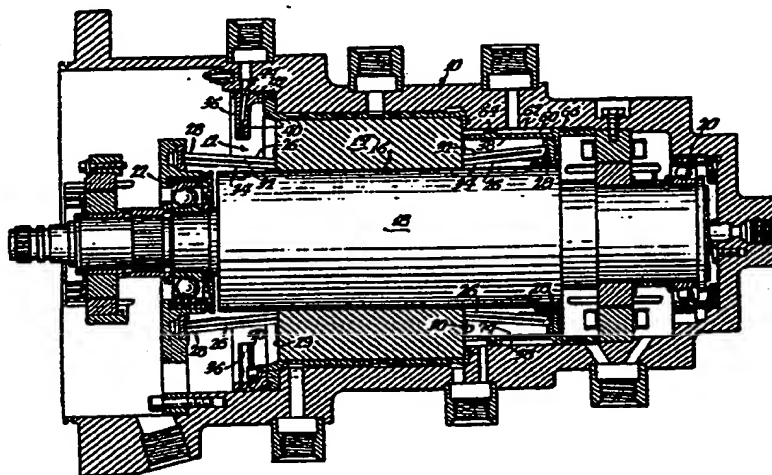




## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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(21) International Application Number: PCT/US84/01768 (22) International Filing Date: 1 November 1984 (01.11.84)  (31) Priority Application Number: 548,945 (32) Priority Date: 7 November 1983 (07.11.83) (33) Priority Country: US  (71) Applicant: SUNDSTRAND CORPORATION [US/ US]; 4751 Harrison Avenue, P.O. Box 7003, Rock- ford, IL 61125 (US).  (72) Inventors: ALEEM, Mohd, Abdul ; 11584 Bend River Road, Roscoe, IL 61073 (US). KRINICKAS, Alex ; 4751 Burning Tree Drive, Rockford, IL 61111 (US).		(74) Agent: WILLIAMSON, Harold, A.; 4751 Harrison Avenue, P.O. Box 7003, Rockford, IL 61125 (US).  (81) Designated States: AT (European patent), BE (Euro- pean patent), CH (European patent), DE, DE (Euro- pean patent), FR (European patent), GB, GB (Euro- pean patent), JP, LU (European patent), NL (Euro- pean patent), SE (European patent).  Published With international search report. With amended claims.

(54) Title: GENERATOR ARMATURE COOLING AND AIR GAP SEALING SYSTEM



## (57) Abstract

During operation of a rotary electric machine coolant tends to enter an air gap between a stator and a rotor thus producing drag losses. This is overcome by an arrangement for preventing the coolant from entering the air gap between the stator and the rotor. The rotary electric machine includes a housing (10) having a stator (12). The stator includes an armature winding (14) with end turns (26) extending from opposite ends thereof. A rotor (18) is journaled (20, 22) within the housing and the stator and is separated from the stator by an air gap (24). At least two nozzles (36, 38) are located within the housing, one adjacent each end of the armature, and directed at an associated set of end turns. A pair of partitions (80) are disposed within the housing, one for each end of the associated end turns and nozzle. A first air gap seal (90, 92) includes a resilient gasket sealingly engaging a corresponding one of the partitions and the tips of the adjacent end turns while a second air gap seal includes sheet-like seals, (94, 111) interposed between layers of the end turns.

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GENERATOR ARMATURE COOLING  
AND AIR GAP SEALING SYSTEM

Description

Technical Field

5           This invention relates to rotary electric machines and more particularly, to a system for cooling armature windings with a liquid coolant and for preventing the coolant from entering the stator-rotor air gap.

10   Background Art

          It has long been recognized that the capacity of rotary electric machines such as motors and generators can be improved by appropriate cooling to dissipate the heat built up during operation which could otherwise deleteriously affect the machine. Thus there have evolved a variety of proposals for such cooling.

          In some, machine windings such as armature windings are provided with hollow conductors through which a coolant is flowed for heat dissipation. One prior art patent representative of this approach is United States Letters Patent 3,634,705 issued Jan. 11, 1972 to Fidei.

          Another approach employed is to spray or otherwise bathe the end turns of armature windings with a coolant. Such an approach is illustrated for example in United States Letters Patents 3,609,420 issued September 28, 1971 to Inagaki et al and 3,648,085 issued March 7, 1972 to Fujii.

          While both approaches provide effective cooling of armature windings such that machine capacity can be increased, both are not without drawbacks. It is obviously expensive to form conduits in conductors for containing the coolant and the distribution of coolant to the hollow conductors is intricate and not well suited to small scale machines.



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At the same time, the approach wherein winding end turns are sprayed has a disadvantage in that any coolant entering the air gap between the rotor and the stator will produce drag losses that may appreciably consume or even eliminate the additional capacity gained by liquid cooling. Inagaki attempts to avoid this difficulty by placing an insulating sleeve in the air gap and extending between stationary parts of the machine to preclude the coolant from entering the air gap. However, the introduction of the sleeve into the air gap increases the overall length of the gap which in turn decreases magnetic efficiency. Fujii appears to employ frusto-conical sleeves extending from opposite ends of the armature and radially inwardly of the end turns. While the Fujii sleeves do not enter the air gap between the rotor and the armature, and thus do not decrease magnetic efficiency, they do not seal against other housing components with the result that a path for the travel of coolant to the air gap, though circuitous in nature, nonetheless exists giving rise to the possibility of the entry of coolant into the air gap with the resultant drag losses.

The present invention is directed to overcoming one or more of the above problems.

#### Summary of the Invention

The invention is directed to a rotary electric machine including a housing having a stator comprised of an armature and windings including end turns extending from opposite ends of the armature. A rotor is journaled within the housing and the stator and separated from the stator by an air gap. At least two nozzles are located within the housing, one adjacent each end of the armature and directed at the associated end turns.



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According to one feature of the invention, an air gap sealing means is provided which includes sheet-like seals interposed between layers of the end turns to intercept coolant and prevent its  
5 flow to the air gap.

According to another feature of the invention, a pair of partitions are located within the housing, one for each end of the armature. Each partition is located axially outwardly of the associated end  
10 turns and nozzles. Air gap sealing means including a resilient gasket sealingly engaging a corresponding one of the partitions and the tips of the adjacent end turns are provided.

Preferably, both features of the invention are  
15 embodied in a given rotary electric machine.

Desirably according to the invention, sheet-like seals are provided to engage and conform to the end turn tips and also engage the gasket to prevent irregularities in the end turn winding from producing  
20 leakage paths. Interstices between conductors forming the end turn tips may be filled with a plastic sealant such as epoxy.

Other objects and advantages of the invention will become apparent from the following specification  
25 taken in connection with the accompanying drawings.

#### Brief Description of the Drawings

Fig. 1 is a sectional view of rotary electric machine, specifically a generator, embodying the invention;

30 Fig. 2 is an enlarged, fragmentary sectional view of the coolant and seal system of the invention as applied to the end turns on one side of the armatur ;



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Fig. 3 is a view similar to Fig. 2 but illustrating the application of the invention to the end turns at the opposite side of the armature; and

Fig. 4 is an enlarged, fragmentary sectional view taken approximately along the line 4-4 in Fig. 2.

#### Best Mode for Carrying Out the Invention

An exemplary embodiment of a rotary electric machine made according to the invention is illustrated in the drawings and with reference to Fig. 1 is seen to be in the form of a so-called brushless generator. The same includes a housing, generally designated 10 in which a stator, generally designated 12 is disposed. The stator 12 includes a core 14 having a central cylindrical opening 16 in which a rotor 18 is journaled as by bearings 20 and 22. As best seen in Figs. 2 and 3, a small air gap 24 exists between the rotor 18 and the armature core 14.

The armature core 14 is provided with windings in the usual fashion. End turns 26 of the windings extend from opposite sides 29 and 30 of the core 14. The end turns 26 terminate in tips 28 which are loop-like in nature and which frequently present an irregular surface as is well known. The windings are also layered having radially inner and outer layers 32 and 34 respectively.

Means are provided for spraying a cooling liquid on the end turns 26. Such means include multiple nozzles 36 and 38, the nozzles 36 being employed to cool the end turns 26 extending from the side 29 of the core and the nozzles 38 being employed to spray the end turns 26 associated with the end 30 of the core 14.



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Although in some instances one of each of the nozzles 36 and 38 spray suffice, preferably, there are a plurality of each of the nozzles 36 and 38 in angularly spaced relation about the end turns 26.

5 In the case of the nozzles 36, the same are provided by radially inwardly directed projections 40 formed integrally on the radial inner surface of a ring 42. The ring 42 has a radially outwardly opening annular groove 44 in its radially outer surface facing an annular surface 46 forming part of the interior of the housing 10. A pair of seal receiving grooves 48 and 50 flank the groove 44 and seal against the surface 46. When the ring 42 is disposed within the housing as illustrated in Figs. 1 and 2, 10 the annular groove 44 is in alignment with a radial bore 52 formed in the housing 10 which serves as a coolant inlet. 15

Each of the nozzles 36, and specifically, the projection 40 forming the same includes an interior bore 54 which terminates at the radially inner end of the projection 40 to define a spray outlet and at the groove 44 to be in fluid communication therewith. Consequently, a coolant introduced into the inlet bore 52 via a fitting 56 will ultimately enter the annular groove 44 to flow about the periphery of the ring 44 to each of the nozzles 36 located thereon. 20 25

The nozzles 38 are also integrally formed in a ring in a nature of a sleeve-like fitting 60. An annular groove 62 is located in the radially outer surface of the ring 60 and is flanked by seal receiving grooves 64 and 66 to establish a seal against an annular surface 68 within the housing 10 as best shown in Fig. 3. 30 A radial bore 70 extends from a fitting 72 through the housing 10 to be in alignment with the groove 62.

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Thus, coolant introduced into the fitting 72 may be flowed around the interior of the groove 62 in the ring 60. The nozzles 38 are formed by a series of radially directed bores extending through the ring 60 into fluid communication with the groove 62.

5 A radially inwardly directed web 80 formed integrally on the ring 60 serves as a partition within the housing 10 axially outwardly of the adjacent end turns 26 and nozzle 38. Preferably, the web 80 terminates in an axially directed flange 82 with a labyrinth sealing surface on its radially inner side. Abutted against the web 80 is an annular, resilient gasket 84. As can be seen in Fig. 3, the tips 28 of the end turns 26 are pressed into the gasket 84 so as to be sealingly engaged thereby. As alluded to earlier, not unfrequently the end turn tips will be somewhat irregular and in order to assure that such irregularities do not provide a flow path between the end turn tips 28 and the gasket 84, sheets of aramid based insulation may be placed thereon. For example, one sheet 90 may be placed on the axially outer ends of the end turn tips 28 while a second sheet 92 may be placed on the inner dimension of the end turn tips 28. The insulation sheets 90 and 92 serve as seals. A suitable material may be that commercially sold under the registered trademark NOMEX.

20 Additionally, to prevent leakage of the coolant fluid to the air gap 24 through the end turns 26 at locations other than at the tips 28, a sheet 94 of an aramid based insulation which also serves as a seal is preferably disposed between the inner and outer layers 34 and 32 of the end turn windings 26.



Turning now to Fig. 2, a partition 100 is disposed within the housing 10 axially outwardly of the end turns 26 emanating from the end 29 of the core 14 and the nozzles 36. The partition 100 includes an axially inwardly opening groove 104 which may receive an annular resilient gasket 106 having the same characteristics as the gasket 84. The end turn tips 28 are pressed into the gasket 106. Sheet-like seals in the form of aramid based insulation may be disposed at the axially outer surface and at the inner diameter of the end turn tips 28 as illustrated at 108 and 110 respectively. The sheets 108 and 110 function identically to the sheets 90 and 92. Similarly, a sheet 111 of aramid based insulation serving as a seal may be disposed between the outer and inner layers 32 and 34 of the end turns 26.

In order to positively assure sealing of the end turn tips 28, the windings at the tips 28 may be impregnated with a plastic sealant 112 as illustrated in Fig. 4. Epoxy resins are satisfactory for the purpose.

From the foregoing, it will be appreciated that the cooling and air gap sealing system of the invention provides sizable advantages over cooling systems heretofore known. The expense of forming conductors as conduits to contain coolant is avoided as is the limitation of such systems on size. Similarly, the air gap 24 may be made of extremely small size maximizing magnetic efficiency of the system. At the same time, paths for flow of the coolant to the air gap are positively sealed through the unique combination of sheets such as the sheets 94 and 111 and the gaskets 84 and 106. The use of the sheets 90 and 92 and 108 and 110

SUBSTITUTE SHEET

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smooth out irregularities in the end turn tips  
to assure positive sealing against the gaskets  
84 and 106. Thus, an inexpensive but positive  
sealing system is provided by the invention with-  
5 out sacrificing efficiency.

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Claims

1. A rotary electric machine comprising:
  - 2 a housing;
  - 4 a stator within said housing including an armature having a winding including layered end turns extending from opposite ends of the armature;
  - 6 a rotor journaled within said housing and said stator and separated from said stator by an air gap;
  - 8 at least two nozzles within said housing, one adjacent each end of said armature and directed at the associated end turns;
  - 10 a pair of partitions within said housing, one for each end of said armature, each being located axially outwardly of the associated end turns and nozzle;
  - 12 first air gap sealing means including a resilient gasket sealingly engaging a corresponding one of said partitions and the tips of adjacent end turns; and
  - 14 second air gap sealing means including sheet-like seals interposed between layers of said end turns.
2. The rotary electric machine of claim 1 wherein
  - 2 said first sealing means further includes sheet-like seals engaging and conforming to said end turn tips
  - 4 and engaging said gasket.
3. The rotary electric machine of claim 2 wherein
  - 2 spaces between conductors forming said end turn tips are filled with a plastic sealant.



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4. The rotary electric machine of claim 1  
2 wherein said housing includes a coolant inlet and  
one of said nozzles is integrally formed on a ring  
4 to open radially inwardly thereof, and a groove in  
the radially outer periphery of said ring and in  
6 fluid communication with said nozzle, said ring  
sealingly engaging an annular interior wall of said  
8 housing with said groove aligned with said coolant  
inlet.

5. A rotary electric machine comprising  
2 a housing;  
a stator within said housing having a winding  
4 including layered end turns extending from opposite  
ends of the armature;  
6 a rotor journaled within said housing and  
said stator and separated from said stator by an  
8 air gap;  
at least two nozzles within said housing, one  
10 adjacent each end of said armature and directed at  
the associated end turns;  
12 a pair of partitions within said housing, one  
for each end of said armature, each being located  
14 axially outwardly of the associated end turns  
and nozzle; and  
16 air gap sealing means including a resilient  
gasket sealingly engaging a corresponding one of said  
18 partitions and the tips of the adjacent end turns.

6. The rotary electric machine of claim 5  
2 wherein said end turn tips are impregnated with a  
plastic sealant.



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7. The rotary electric machine of claim 5  
2 wherein irregularities in said end turn tips  
are smoothed by sheet-like seals engaging said  
4 tips and said gasket.

8. The rotary electric machine of claim 5  
2 wherein said end turn tips are pressed into said  
gasket.

9. A rotary electric machine comprising  
2 a housing;  
a stator within said housing having a winding  
4 including layered end turns extending from opposite  
ends of the armature;  
6 a rotor journaled within said housing and said  
stator and separated from said stator by an air gap;  
8 at least two nozzles within said housing, one  
adjacent each end of said armature and directed at  
10 the associated end turns; and  
air gap sealing means including sheet-like  
12 seals interposed between layers of said end turns.

10. The rotary electric machine of claim 9  
2 wherein said sheet-like seals are formed of insulating  
material such as aramid or the like.



## AMENDED CLAIMS

[received by the International Bureau on 8 April 1985 (08.04.85);  
original claims 5, 7 and 10 amended; claim 11 added; other claims  
unchanged (2 pages)]

2        4.    The rotary electric machine of claim 1 wherein  
said housing includes a coolant inlet and one of said  
nozzles is integrally formed on a ring to open radially  
4        inwardly thereof, and a groove in the radially outer  
periphery of said ring and in fluid communication with  
6        said nozzle, said ring sealingly engaging an annular  
interior wall of said housing with said groove aligned  
8        with said coolant inlet.

2        5. (amended) A rotary electric machine comprising  
a housing;  
a stator within said housing having a winding  
4        including layered end turns extending from opposite ends  
of the armature;

6        a rotor journaled within said housing and said  
stator and separated from said stator by an air gap;  
8        at least two nozzles within said housing, one  
adjacent each end of said armature and directed at the  
10       associated end turns;

12       a pair of partitions within said housing, one for  
each end of said armature, each being located axially  
outwardly of the associated end turns and nozzle; and

14       air gap sealing means including a resilient gasket  
sealingly engaging a corresponding one of said partitions  
16       and the tips of the adjacent end turns said end turn tips  
being impregnated with a plastic sealant.

2        6.    The rotary electric machine of claim 5 wherein  
said end turn tips are impregnated with a plastic sealant.



2 7. (amended) The rotary electric machine of claim 5  
wherein irregularities in said end turn tips are smoothed  
by sheet-like seals engaging said tips and said gasket.

2 8. The rotary electric machine of claim 5  
wherein said end turn tips are pressed into said gasket.

2 9. A rotary electric machine comprising  
a housing;  
4 a stator within said housing having a winding  
including layered end turns extending from opposite ends  
of the armature;  
6 a rotor journaled within said housing and said  
stator and separated from said stator by an air gap;  
8 at least two nozzles within said housing, one  
adjacent each end of said armature and directed at the  
10 associated end turns; and  
12 air gap sealing means including sheet-like seals  
interposed between layers of said end turns.

2 10. (amended) The rotary electric machine of claim  
1 wherein said sheet-like seals are formed of insulating  
material such as aramid.

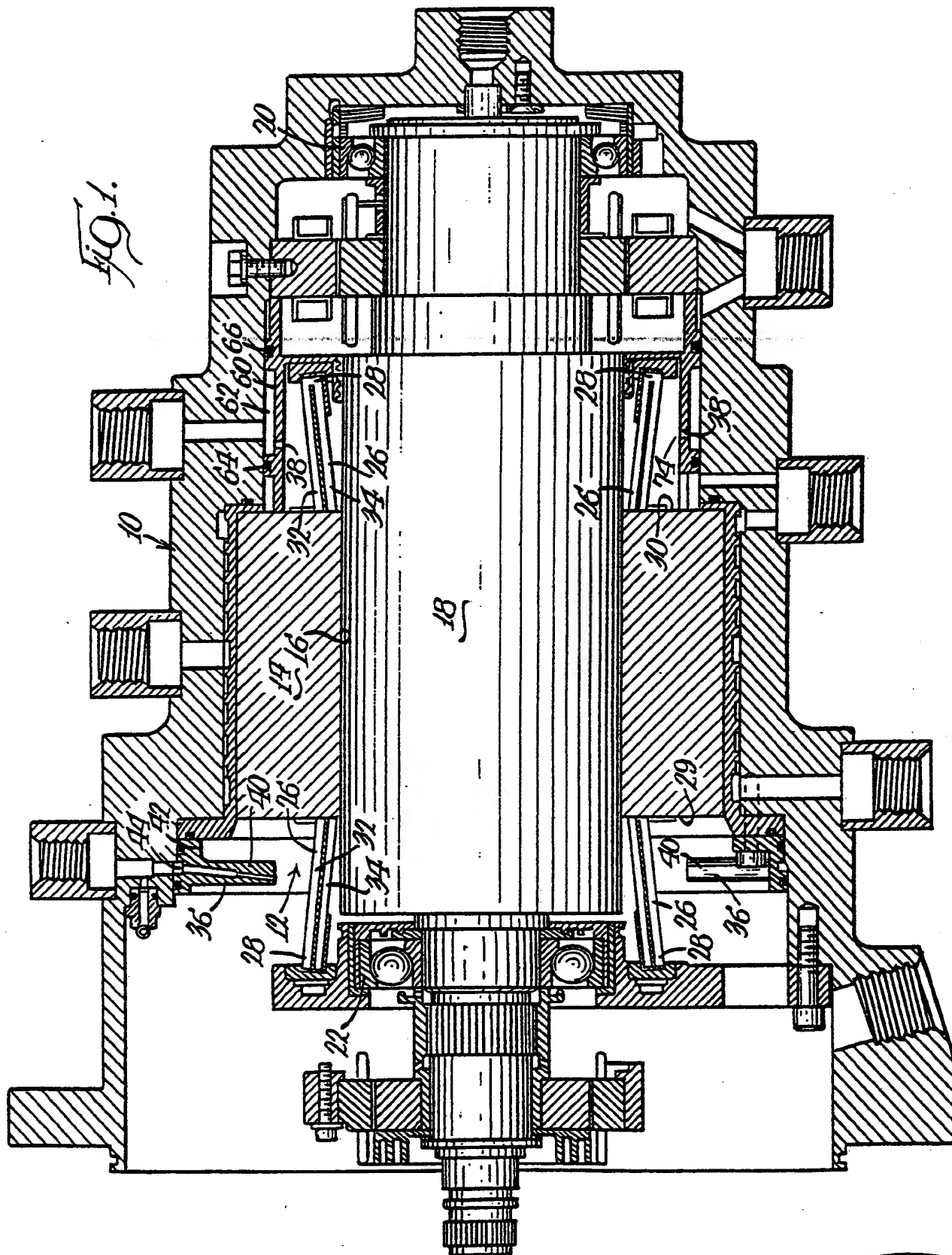
Please add the following claim:

2 11. The rotary electric machine of claim 1  
wherein there are a plurality of said nozzles adjacent  
each end of said armature and located radially outwardly  
4 of the associated end turn and directed thereat.

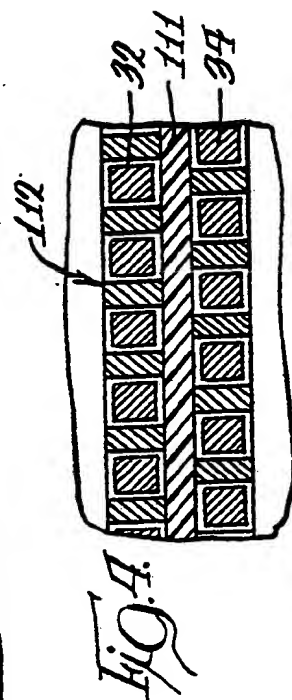
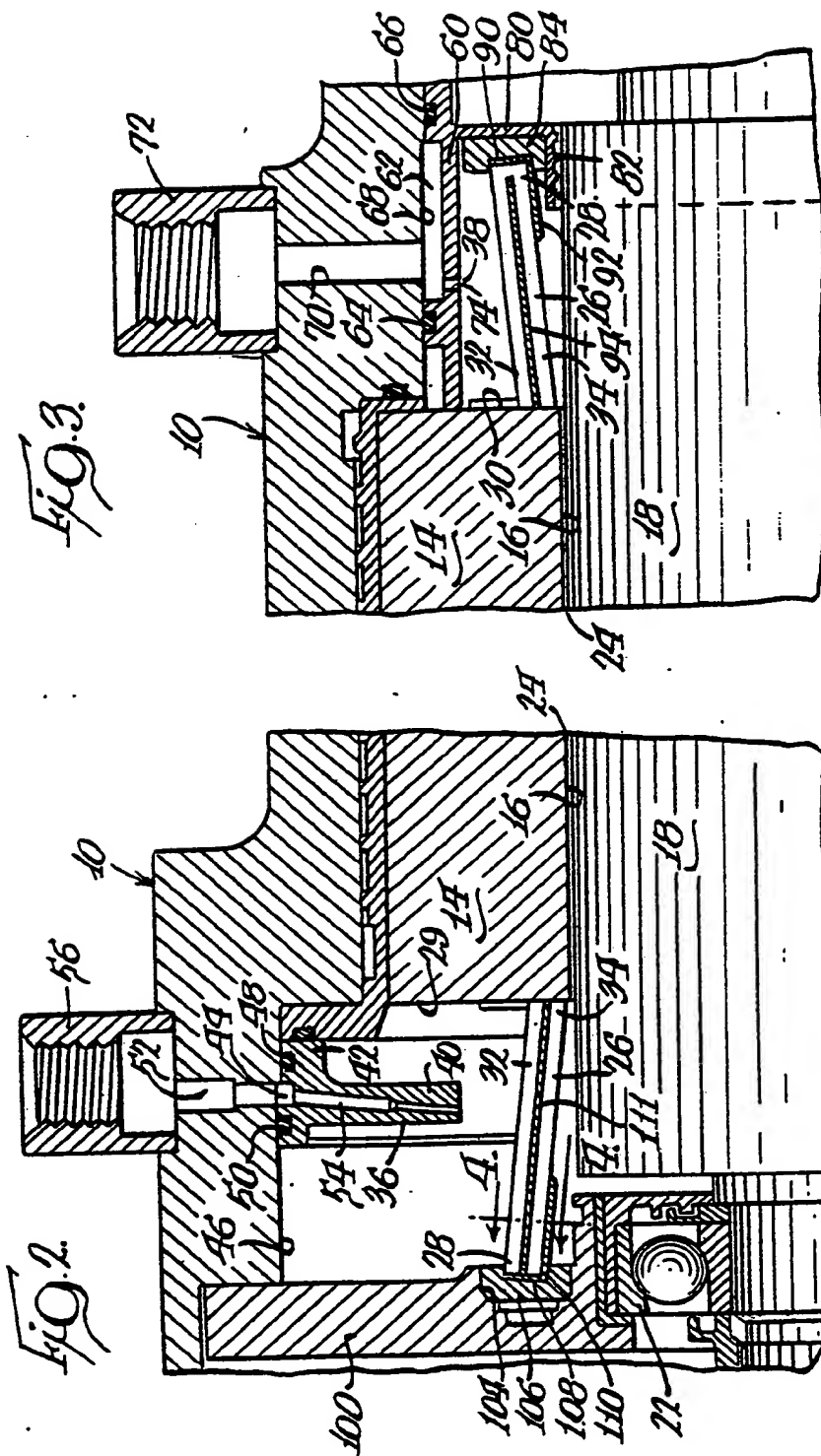


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FIG. 1.







# INTERNATIONAL SEARCH REPORT

International Application No PCT/US84/01768

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (If several classification symbols apply, indicate all) <sup>3</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
INT. CL. <sup>3</sup> H02K 1/04, 12, 9/00, 9/08, 5/10 F16J 15/48, 15/00; E21B 33/00		
US CL. 310/43, 52, 54, 57, 58, 59, 60R, 64, 65, 85, 86, 88 277/57, 59, 80		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>4</sup>		
Classification System	Classification Symbols	
U.S.	310/43, 45, 52, 54, 57, 58, 59, 60R, 64, 65, 85, 86, 88, 260 277/57, 59, 80	
Documentation Searched other than Minimum Documentation to the extent that such Documents are included in the Fields Searched <sup>5</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT</b> <sup>14</sup>		
Category <sup>6</sup>	Citation of Document, <sup>15</sup> with indication, where appropriate, of the relevant passages <sup>17</sup>	Relevant to Claim No. <sup>18</sup>
Y	US, A, 3,648,085 (FUJII) 07 MARCH 1972	1-10
Y	US, A, 3,609,420 (INAGAKI ET AL) 28 SEPTEMBER 1971	1-10
Y	US, A, 3,355,600 (PENN) 23 JANUARY 1961	1-10
Y	DE, B, 1,097,019 (HORSLEY) 12 JANUARY 1961	1-10
A	US, A, 3,975,655 (BEERMAN ET AL) 08 AUGUST 1976	
A	US, A, 3,075,103 (WARD, JR) 22 JANUARY 1963	
<p><sup>16</sup> Special categories of cited documents: <sup>15</sup></p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search <sup>1</sup>	Date of Mailing of this International Search Report <sup>2</sup>	
07 FEB 1985	08 FEB 1985	
International Searching Authority <sup>1</sup>	Signature of Authorized Officer <sup>20</sup>	
ISA/US	Robert Skudy ROBERT SKUDY	